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### **Paper No. 5: The Shipyard Product Information System as an Aid to Implementing More Productive Strategies**

U.S. DEPARTMENT OF THE NAVY  
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**R** RESEARCH  
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IN  
SHIPBUILDING

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**THE SHIPYARD PRODUCT INFORMATION SYSTEM AS AN AID  
TO IMPLEMENTING MORE PRODUCTIVE STRATEGIES**

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The REAPS shipyards have recently endorsed the first phase of a long term project to specify, design and implement a Product Information System. It is anticipated that the eventual output of this project will be a photo type information system consisting of a database and associated utility software, which will be useful to a variety of functions in the yard which record or supply technical and production-oriented product information. While this may sound like a substantial undertaking (and it is) the benefits of the use of such a capability are equally substantial. The purpose of this presentation is to highlight some of the more significant of these benefits.

First we need to look at what is meant when we talk about a Product Information System for shipbuilding. The heart of the system is a logically-structured, product-oriented database which we call the product model. The phrase "product model" is perhaps a bit of a misnomer because, as we'll see, information about the yard itself is also maintained. In fact the linkage between product and yard facility information in the database is the source of one of the most important benefits of the Product Information system.

The product model consists of a set of so-called "logical models" which represent logically complete database subsets tailored to the needs of specific yard functions.

For example, there would exist a structural design model, design models for various distributive systems, a material control and production control model, etc. Each such model can be explicitly linked to, or overlap, other models in the database where there is benefit in doing so. This is another major source of benefits of the product model approach. Fig. 1 depicts the basic constituents of the Product Information System.

In order to depict models of information we have settled on the notation shown in Fig. 2 wherein the boxes represent entities or items about which we want to record information, such as parts of drawings, and the arrows represent relationships between entities. The counterpart of an entity in a database can be considered to be a file of information that contains a series of records each of which holds information about a specific instance of the entity, as for example a specific part. Relations are represented by pointer chains in the database linking specific records in the entity files.

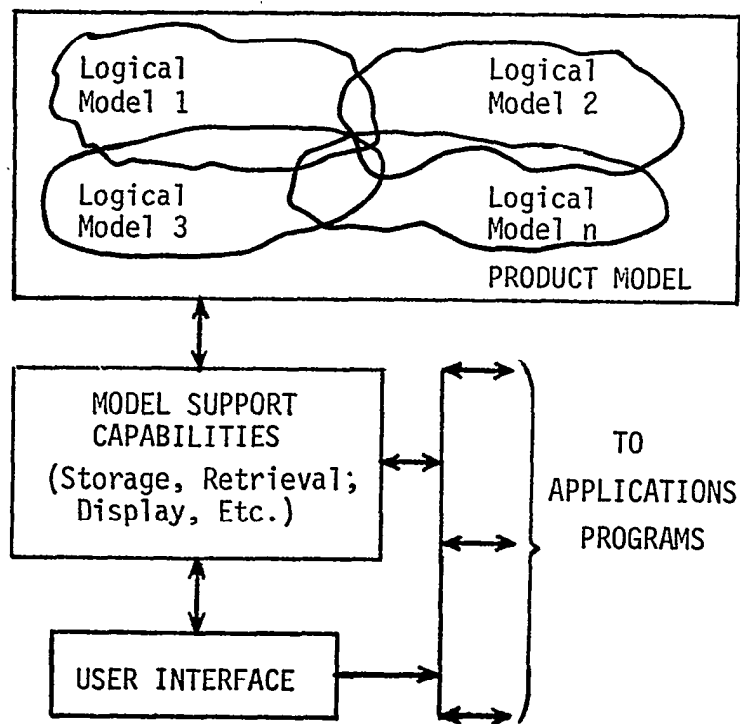


Figure 1. Product Information System Layout

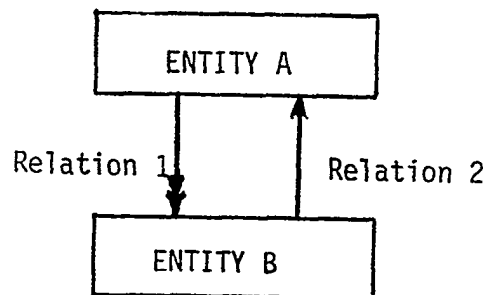


Figure 2. Information Model Notation

In Fig. 2 the double arrow pointing to entity B indicates that many B's may be related to a single entity A via relation 1 while the single arrow indicates that at most one A is related to a single B via relation 2.

Now lets look at some of the payoff areas for the use of a Product Information System

### Benefits in Design

The benefits of using a database approach to record the design fall largely into two categories: first, the improved ability to manage the design configuration and second, the increased speed and accuracy with which design documentation can be produced.

The major purpose of design information models is to document the physical characteristics of the design; in particular its geometry, arrangement and material requirements. To demonstrate how this might be done Fig. 3 represents a simplified design model for structure.

The principal component of this model is the Structural Definition Entity (SDE). An SDE may be a point, a line, surface, a volume (or region), a plate part, a stiffener or a group of parts. Material type is recorded for stiffeners and plates separately such that they can be easily collected to determine total material requirements. Non-derivable geometry for lines and surfaces is maintained in the Geometry Directory. Geometry that can be derived is not recorded explicitly until a formal approval is issued. This reduces database size and simplifies the task of making design changes.

Drawings showing several SDE's can be defined and subsequently produced (by a drawing processor) automatically. We can also record for each SDE the defined Drawings it appears in such that when changes are made to any SDE we can automatically determine which drawings are affected and therefore may need to be regenerated, thus simplifying design management.

The structural arrangement is recorded by means of stating the, geometric or piece Boundaries of each SDE in terms of other SDE's. For structural pieces bounded by other structural pieces a Joint is also defined which may reference a line SDE to specify the geometry of the joint.

Stiffener end boundaries may reference an executable Procedure, similar to current N/C system norms, which defines stiffener end cut geometry. In fact the geometry of plated parts, in particular brackets, may be entirely defined by such a procedure reference.



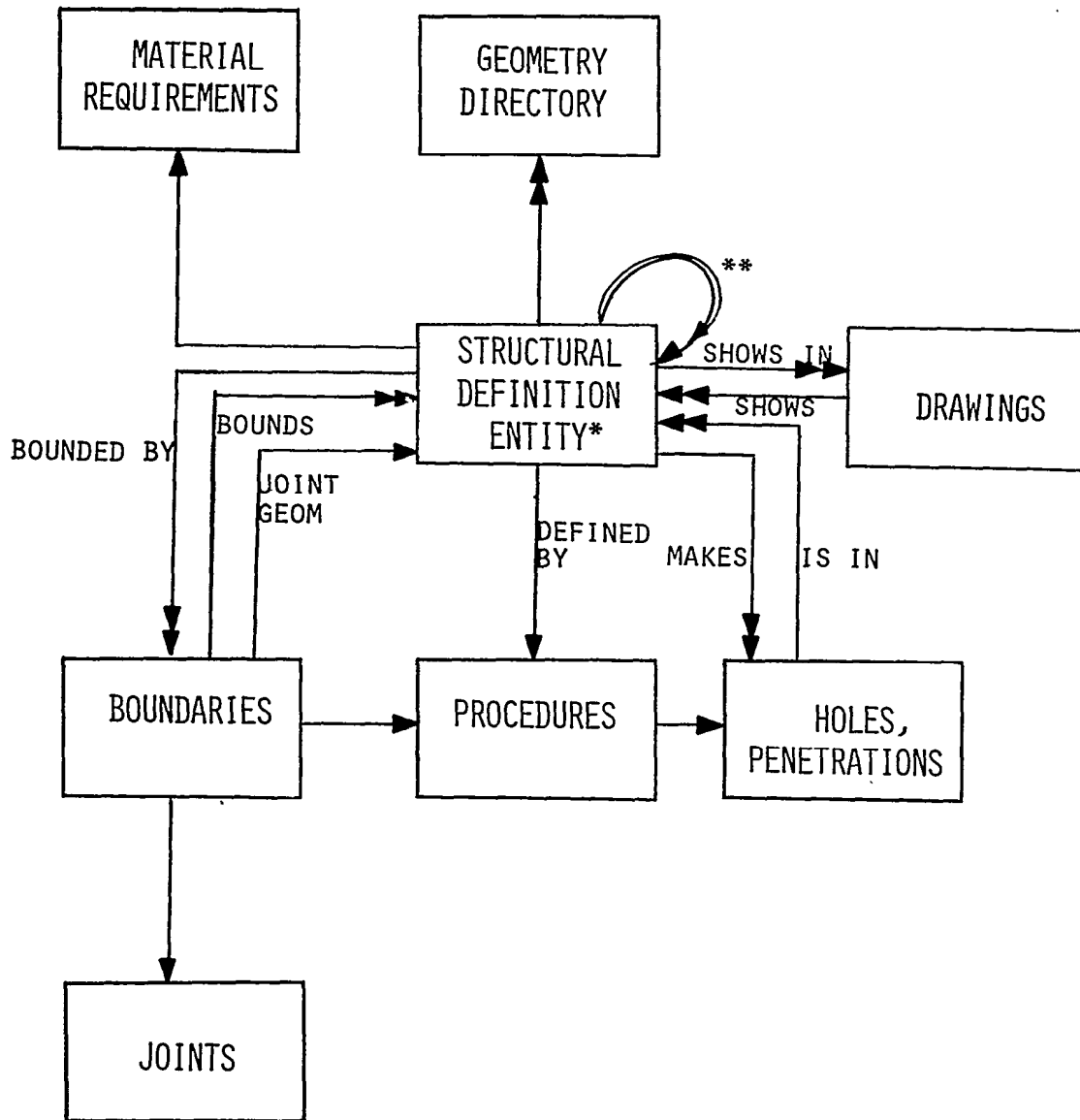


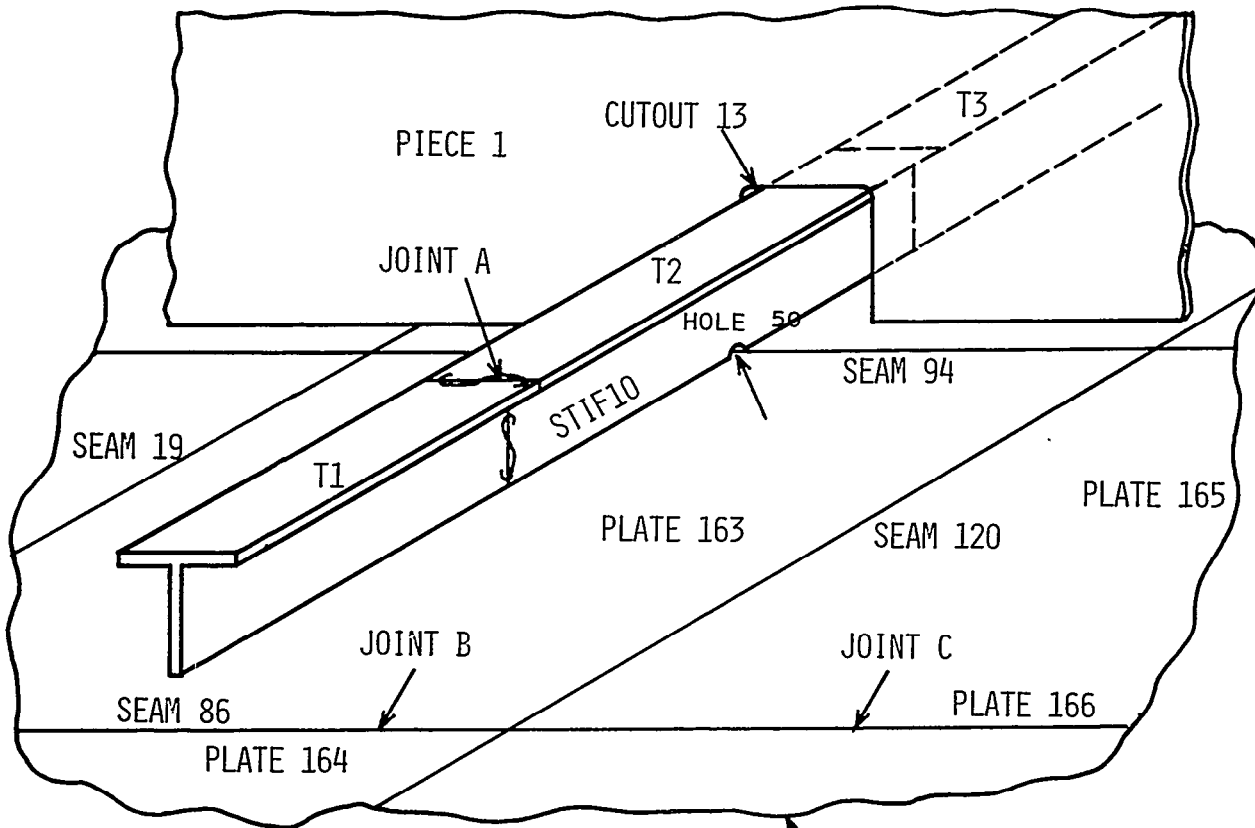
FIGURE 3. SIMPLIFIED STRUCTURAL DESIGN MODEL

\* POINTS  
 LINES  
 SURFACES  
 VOLUMES (REGIONS)  
 PLATE PARTS  
 STIFFENERS  
 GROUPS

\*\* CONTAINS; IS PART OF  
 TRAVERSED BY  
 REGION CONTAINS  
 GROUP CONTAINS  
 SYNONYMS FOR  
 IDENTICAL TO

Finally the holes in structure created by an SDE are recorded which results in the automatic recording of all holes in a given structural entity. The geometry of such holes may be specified by a Procedure.

Fig. 4 illustrates the usage of the relations which document the structural arrangement.



**SURF A:**

- CONTAINS PLATES 163,164,165,...
- BOUNDS PIECE 1, STIF 10,
- IS TRAVERSED BY PIECE 1, STIF 10

**PLATE 163:**

- IS PART OF SURF A
- IS BOUNDED BY PLATE 164  
MAKING JOINT B WHOSE  
GEOMETRY IS SEAM 86

**STIF 10:**

- CONTAINS T1,T2,T3,...
- MAKES CUTO 13 IN PIECE 1,  
HAS HOLE 50
- IS BOUNDED BY SURFA,...

**T2:**

- IS PART OF STIF 10
- IS BOUNDED BY T3 AND T2  
(CREATING JOINT A)

Similarly, a design information model for piping has been developed for use in the RAPID Pipe Detailing System and is depicted in Fig. 5. The primary entity in this model is the Part which may be a pipe piece, valve, fitting or piece of equipment. Parts may be grouped to include for example all those within a system or those within a manufacturable detail. Standard valves and fittings are defined

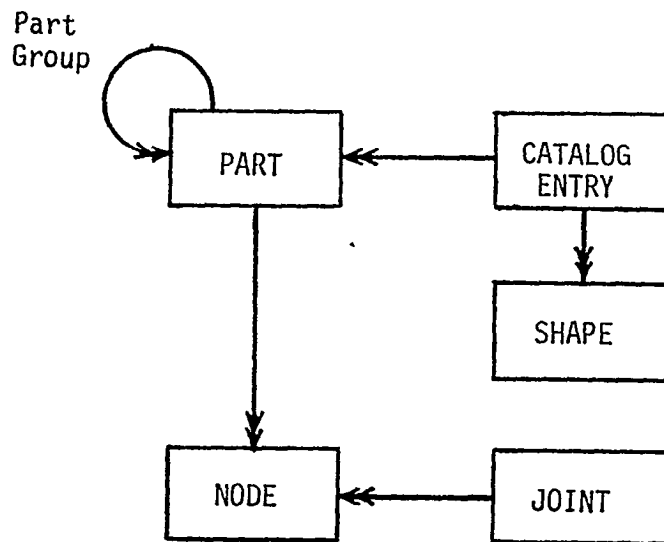
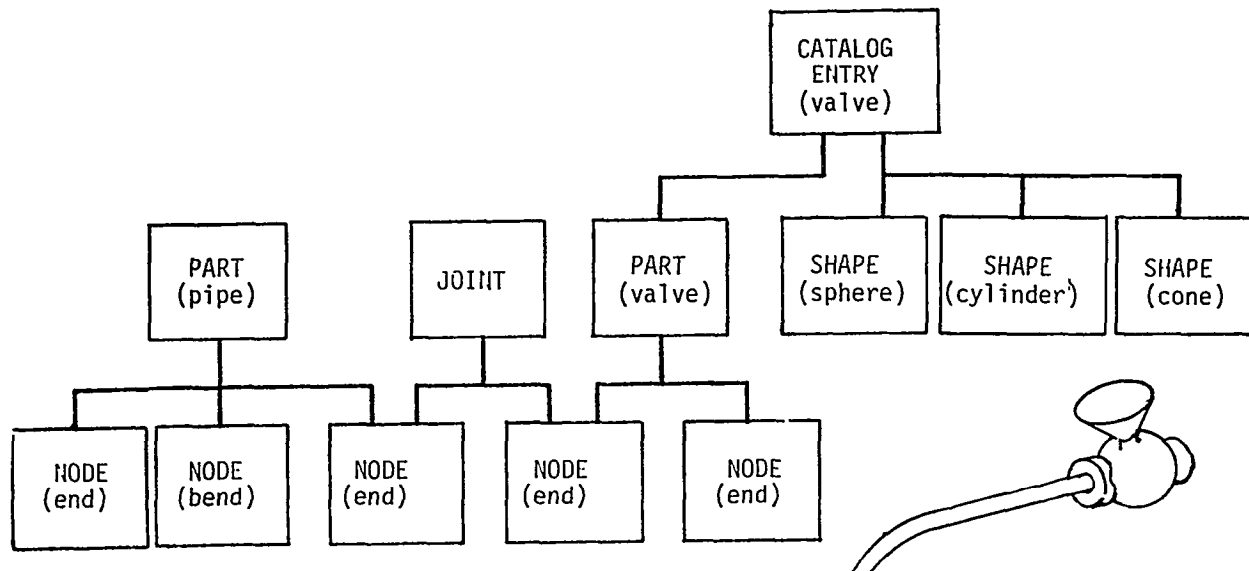


Figure 5. RAPID System Information Model

in a catalog and their use as unique parts in a system is recorded by the Catalog-Part relation. Each Catalog entry may be represented by several Shapes for drawing purposes. Part location and orientation is defined by Node entities which also serve to locate the position of internal reference points such as bend locations, hangar attachment points, sleeve locations, etc. The two end nodes of attaching components are referenced by the Joint entity which records the particular joint detail.

Fig. 6 depicts the data structure that would be created within this model to represent a simple detail.

Similar models could be defined to represent other systems and outfit items. Once these models are defined the relations to link them could also be established. This linkage would offer the opportunity to perform interference checking, either in a semiautomated or completely visual way by producing composite drawings in any desired view, and to record penetrations through and attachments to structure created by the various systems. One could also define a relation for compartments



**Figure 6. Example Instance of Piping Model**

and spaces which identified all system components, pieces of equipment as well as furniture within them for the purposes of verifying contract-specified equipment lists for the spaces and automatically producing space arrangement drawings for early owner approval.

Fig. 7 summarizes the benefits in design of the use of such models.

1. ABILITY TO AUTOMATICALLY PRODUCT DESIGN DOCUMENTATION (DRAWINGS AND LISTS)
2. ABILITY TO REVISE DESIGN QUICKLY AND MANAGE DESIGN CONFIGURATION MORE EFFECTIVELY.
3. LINKAGE OF VARIOUS "SYSTEM" MODELS PROVIDES THE INFORMATION BASE FOR INTERFERENCE CONTROL.
4. USE OF STANDARDS WOULD BE ENCOURAGED.

**Figure 7. Design Benefits Summary**

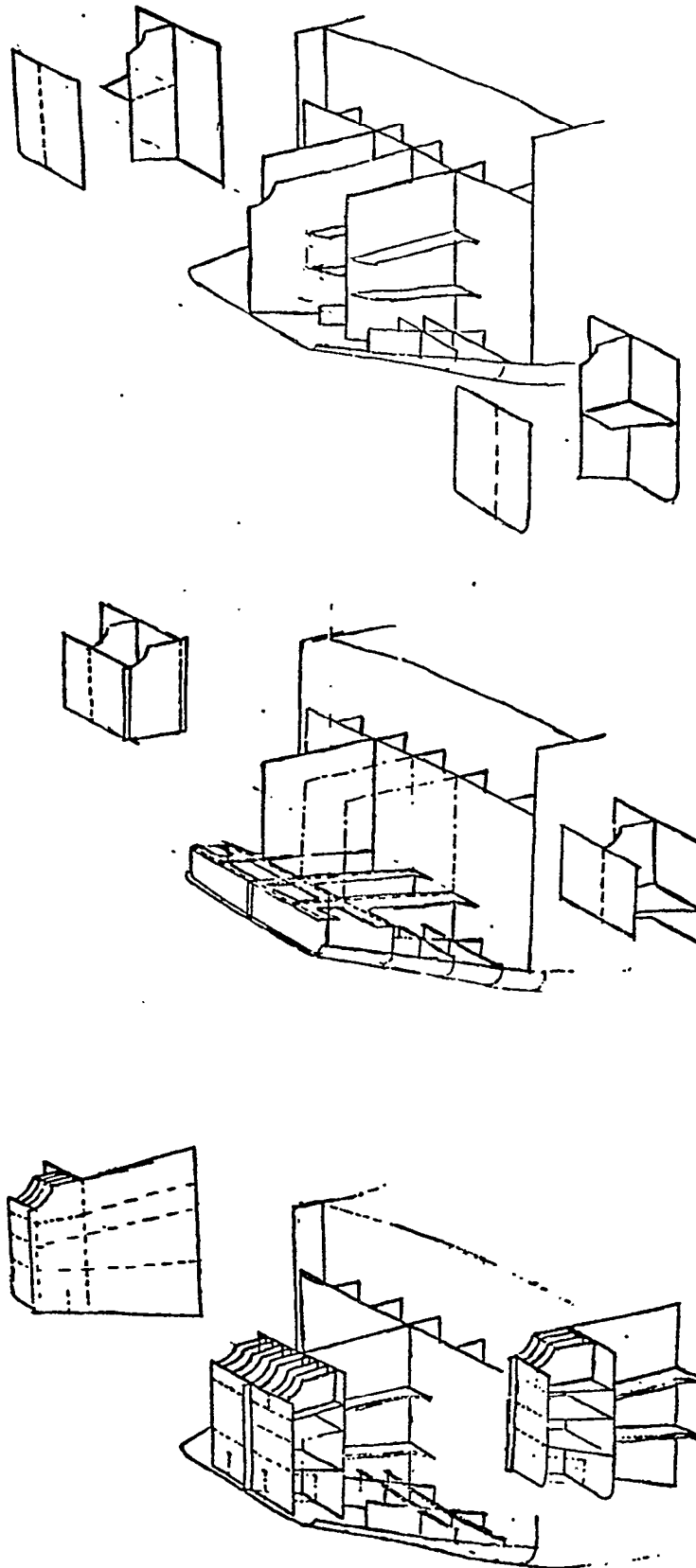
However, the most important feature of these models is that they document the design completely for use by other yard functions in terms of its material requirements, its physical arrangement and the parameters of the design which define its work content (such as square footage for coating, joint type and length for welding and cutting path lengths for burning, etc.). As this information is collected, material control can access it to acquire material requirements for issuing purchase orders, and planners can access it to begin defining production units (or interim products) and to define and schedule work packages.

#### BENEFITS IN PLANNING

The first payoff for planning (i.e., tactical production planning as opposed to strategic or long range planning) is the availability of the current design definition on a computer as opposed to on pieces of paper in the form of drawings and lists. As a result, early stage planning of structural units could benefit by being able to slice up the design in various ways and produce computer-generated drawings of the defined units for all desired views. Figures 8 and 9, taken from [5] show the type of product visualization needed at this point in planning. This would aid greatly in determining the producibility of the unit and aid in planning material handling requirements for turn overs as well as lifting, as the weight and center of the candidate unit would be directly available from summing these parameters for the design-defined components it contained. Several options for unit configuration could be reviewed quite quickly in this way.

Later on in Structural Planning the object is to develop a fabrication plan which makes effective use of shop facilities and labor while meeting a production schedule dictated by the sequence of erection. These two goals may be conflicting as pointed out by Ruehsen [5]. As one of the planner's greatest handicaps currently is lack of detailed product and facility information he generally will elect, justifiably, a conservative plan and accompanying schedule as a hedge against this uncertainty.

The planner needs to know as much as possible about the projected loads on fabrication shop facilities, the assembly unit product structure and schedule, and the material requirements of the components in these units in order to develop an effective fabrication plan and schedule. The product model could supply this information and allow the planner to "try out" several alternatives prior to committing to a plan and schedule. For example, various nest arrangements and sequences could be quickly evaluated, including cross unit nests, trading off the need for



**Figure 8. Hull Planning Graphics**

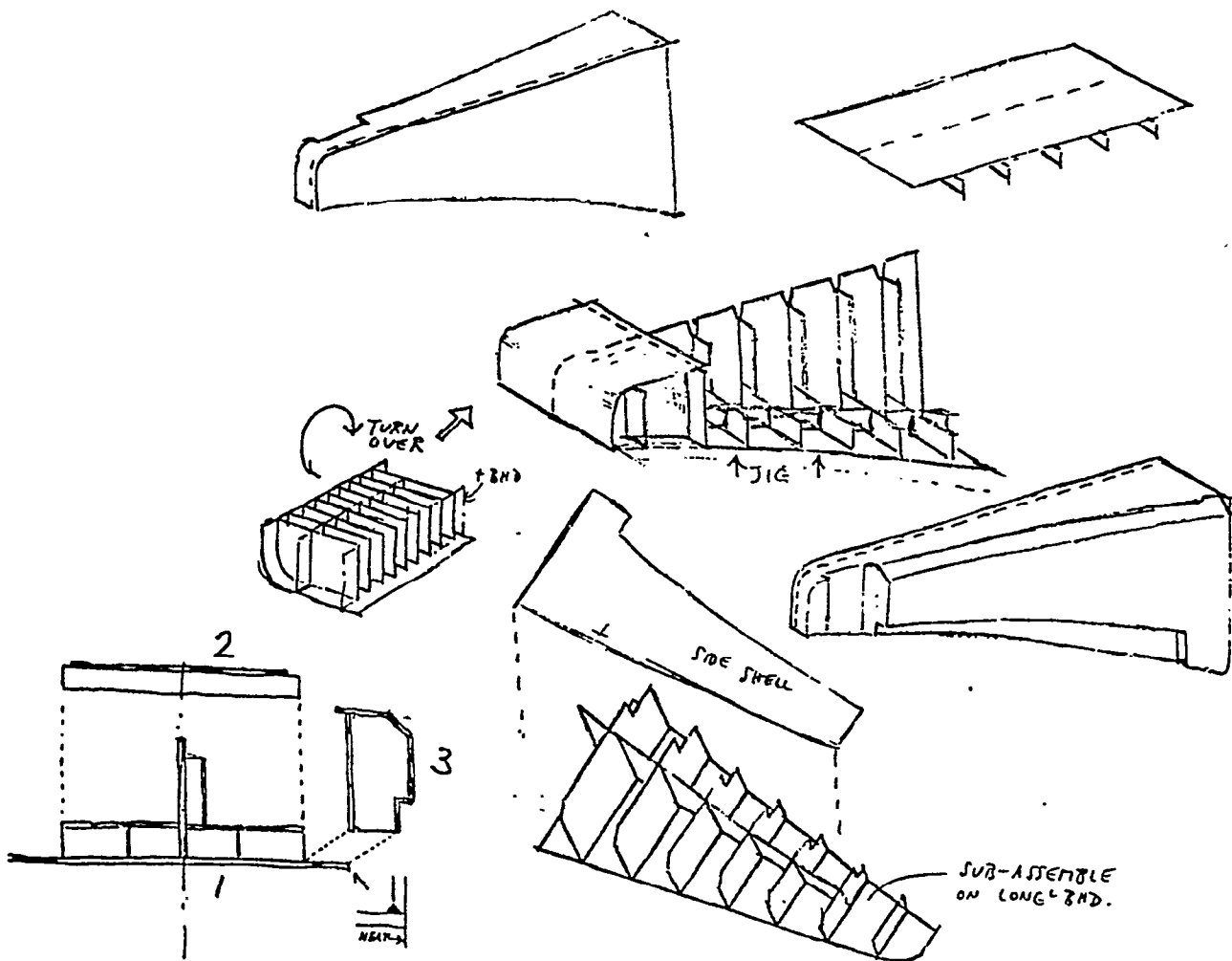


FIGURE 9. Assembly Planning Graphics

in-process material buffer storage against efficient material usage, handling and shop loading.

Fig. 10 depicts a simplified information model for structural production which depicts the major information entities and relations the planner needs to make use of.

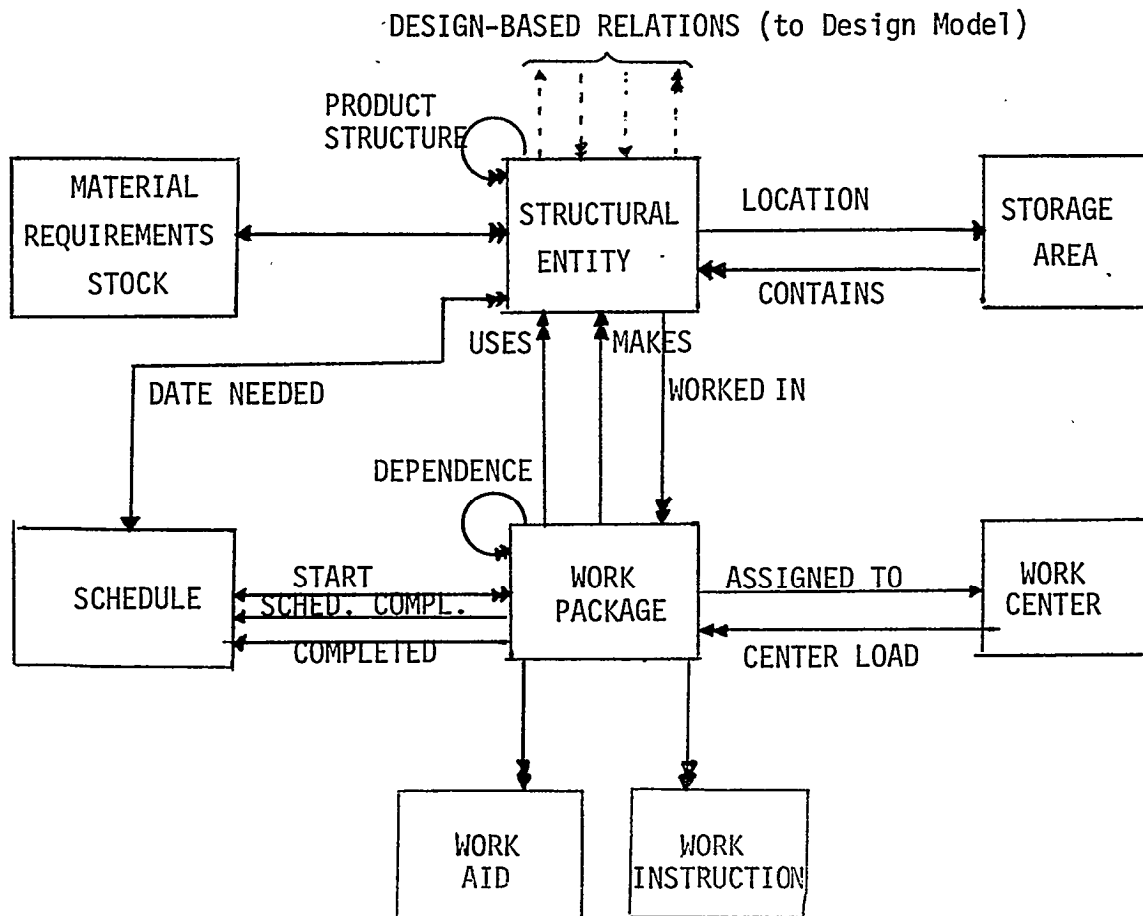


Fig. 10. Simplified Production Model

In this model "Structural Entities" are initially the set of individual parts resulting from detailed design, requiring fabrication and subsequent assembly. Each such item retains its identity in terms of the structural design through its linkage, via the "Design-Based Relations" to the structural design model. Also, each structural item at the component level to be fabricated will require a particular stock type, thus, Its relation to "Material Requirements".



Given component-level parts and their material requirements as a starting point the planner can begin to "build" the assembly "Product Structure", identifying those items contained in a subassembly, subassemblies in an assembly, etc. while defining a 'Work Package' to accomplish each assembly job (which would identify the components it "Uses" in creating the assembly it "Makes"). Each work package once fully designed, would have associated with it the "Work Aids" it required (e.g. N/C tapes, jigs, molds, sketches, etc.) and the "Work Instructions" (e.g. assembly sequence, welding process, dimension checks, etc.) needed to carry it out. Those packages which must be completed prior to initiating the current package could be identified via the "Dependence" relation.

The planner could then identify a tentative assembly schedule noting the "Date Needed" of the completed item (based on the erection schedule), and from this estimate necessary "Start" and 'Scheduled Completion" dates for the candidate work packages.

Fabrication work packages and tentative schedules could be subsequently defined. Such packages could "Make" one part (e.g. a shell plate) or many parts (e.g. through cutting a nest). The nesting job itself is aided by the relation identifying all parts of a particular material type, their needed dates and the product structure relation. These relations could be used to perform a composite search of the data to return that set of parts, of a particular material type, required by a given date that are included within a specified set of assemblies or units. From this list of parts a set of fabrication work packages could be developed, and their accompanying schedule assigned.

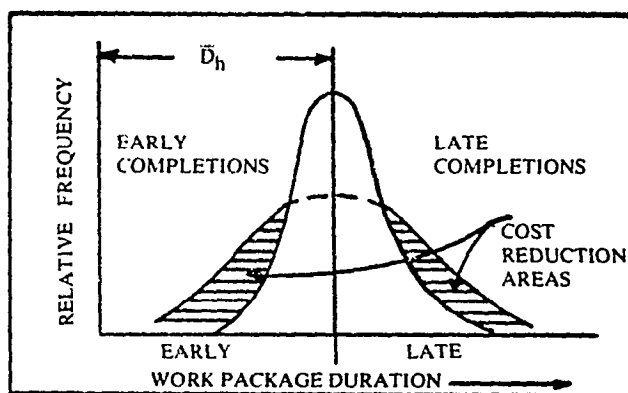
Each work package would be "Assigned To" a particular "Wrk Center" and the group of all work packages assigned to a particular center identified, via the "Center Load" relation, thus providing the basis for assessing facility loads.

Making use of an information base such as that of Fig. 10 the planner then could try out various product structure configurations and candidate work package definitions and schedules in an attempt to develop an efficient structural production plan. Projected work center loadings and 'Storage Area" inventories could be assessed quickly during this process to determine uneconomic or infeasible situations. The end result of this process would be a production plan based on the best available information, which would reside on the computer ready for use by production control.

Therefore if a yard does elect to nest on a unit basis, or schedule fabrication jobs which are closely tied to the erection schedule, it ought to do so because these strategies will lead to the most cost or time effective production. It need NOT do so because a lack of information makes any other plan too risky or too cumbersome to manage.

The next benefit for the planning function comes not from the use of a product model per se but from inclusion within the model of engineered standards data. For our purposes these standards which are discussed in some detail in [4], produced by Bath Iron Works under the auspices of the National Shipbuilding Research Program (NSRP), document standard labor budgets and job durations for those processes and operations for which they have been established in the yard. One of the primary objectives of using such standards is to produce more reliable work package schedules; that is to reduce the variance in work package labor budgets and durations as depicted in Fig. 11 taken from the Bath report [4]. Quoting from that report:

"Both early and late work package completions have unfavorable impact on construction costs. Work that is completed early must be stored, thereby incurring unnecessary material handling costs and inventory carrying charges. Work that is completed late usually entails expediting and overtime costs. Reducing the variance of work package duration distributions will permit tighter scheduling of work, thereby reducing the cost of early and late completions, as shown in ... "(See Fig. 11). This is a primary objective of improving the accuracy and reliability of the planning and scheduling process. In order to do that however, a firm and reliable basis is needed for determining the amount of real work in each package and how long it will take to accomplish it. Planning and scheduling can be tightened up ONLY if such a basis exists. Otherwise the plan will simply misrepresent the real duration, and scheduling will be even less credible than it was before."



**Figure 11. Benefit of Compressing Dispersion of Work Package Duration**

Given the availability of such standards in our product model, and having already recorded the pertinent design parameters used in applying these standards, work package labor budgets and durations could be automatically calculated. These estimates could then be used to establish the schedule.

Fig. 12 depicts an information model that would support this process. (The use of this model is discussed in the next section.)

Additionally, provided a suitable scheduling program was available, the schedule itself could be automatically or semi-automatically determined as a result of executing a strategy to level-load facilities and/or manpower.

#### **OUTFIT PLANNING**

Fig. 12 was generated originally to document how a Product Information System could support the processes of "Outfit Planning" [6] again produced within the NSRP and sponsored by Todd Pacific Shipyards.

Without going into detail the major objective of the outfit planning methodology, as practiced by some of the most competitive yards in the world, is to plan the production and assembly of outfit units in shops for the purposes of:

- o achieving shorter contract award to delivery times
- o reducing total cost
- o achieving better quality
- o improving worker safety

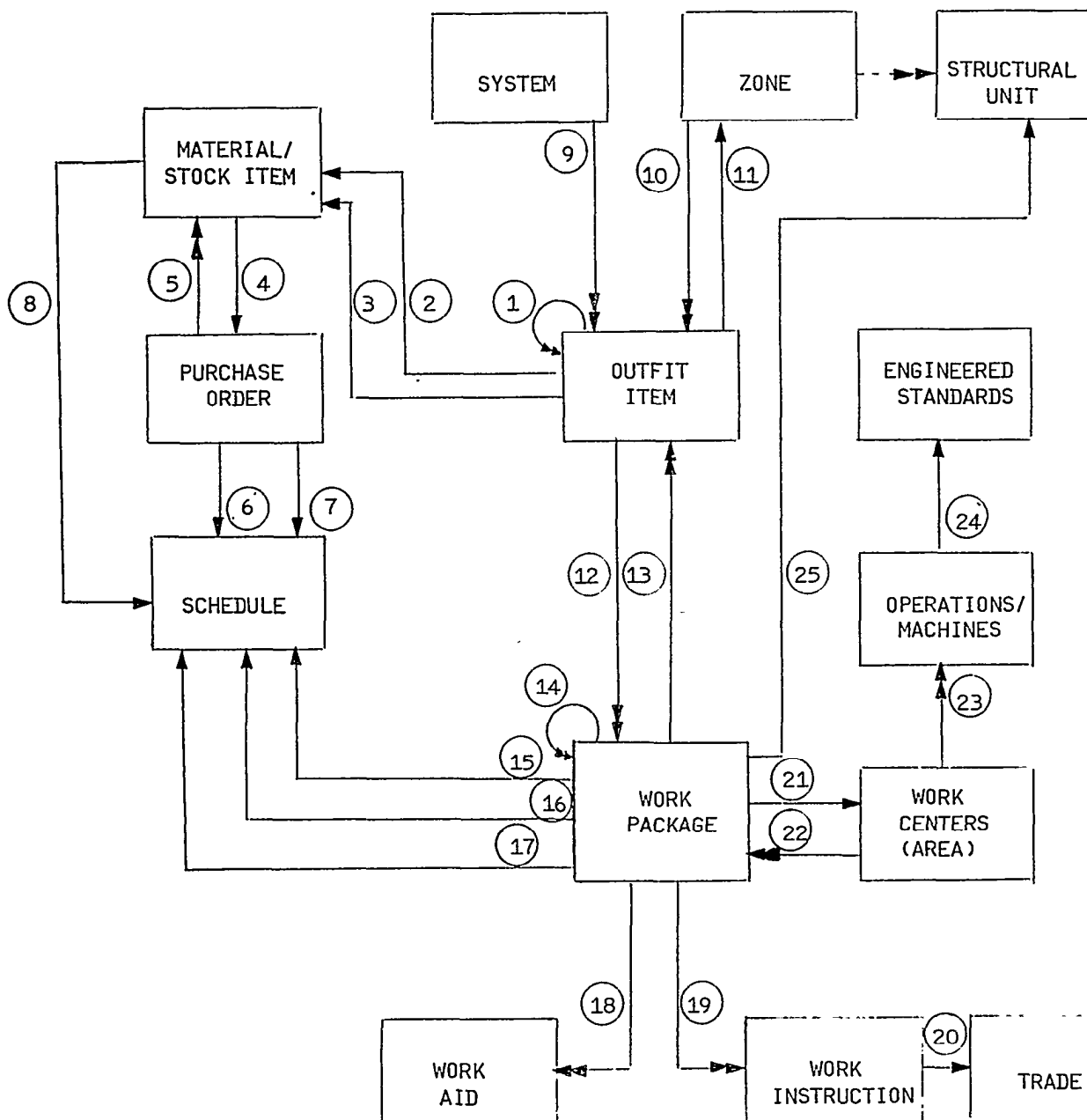


Fig. 12. SIMPLIFIED OUTFIT PLANNING/PRODUCTION DATABASE

Three rather key features of the methodology are that the outfit design and planning functions are intimately linked, that they are linked because their principal product is the definition of modular, sometimes multisystem units called "interim products", and that the design and planning of these units is controlled largely on the basis of geographical regions in the ship called zones.

The fundamental entity in the model in Fig. 12 is the Outfit Item. This may be a single component (e.g. a flange fitting) or the collection of components via ①, composing an outfit "unit". Component-level items may be purchased stock items (e.g. the flange), ②, or components fabricated from raw stock (e.g. a pipe piece or HVAC duct) ③. (Purchased stock items could be additionally classified, as is done at IHI, as renewable inventory stock or "allocated" stock material.)

Each Material Item procured on a contract basis appears on a purchase order, ④, and each purchase order may reference many items ⑤. Each P.O. is related to the Schedule via the date of its issuance ⑥ and the planned receipt date ⑦. Each Material Item also has recorded about it its actual receipt date in the yard ⑧.

A System (defined in design) is composed of many component-level items ⑨. Similarly each Zone may contain Outfit Items, component-level or not ⑩, while each unique Outfit Item will be located in a single Zone ⑪ (although the particular Zone it is in may change over time as Zone definitions change.)

An Outfit Item may be called out in more than one Work Package ⑫ (as long as it is not physically transformed) and a particular Work Package may reference many Outfit Items ⑬ as in an assembly operation.

A Work Package's dependency on the completion of other packages can be stated ⑭ along with its "start", "needed" and "completed" dates ⑮, ⑯, ⑰.

A Work Package may require several Work Aids ⑱ such as jigs, templates, shop sketches etc. and may consist of a series of individual Work Instructions ⑲. Each instruction could reference the Trade used to carry out the instruction ⑳.

The Work Package is assigned to a particular Work Center (Area) (21) and each Work Center may at any given time have several Work Packages scheduled for it (22). A Work Center may utilize several machines and many operations may be carried out (23). An Engineered Standard may be established for each operation. Finally where an Outfit Item is to be installed "On-Block" a relation (25) is needed to identify the particular structural unit into which it is to be integrated.

As previously mentioned the design-oriented product description is directly linked to the production-oriented description. As a result design-specified information which serves as input to work content-estimating relationships based on engineered standards application (e.g. area of surface to be coated, length of welded joints for various processes, number of flanged joints to be bolted, etc.), is directly available. Therefore labor budgets and total process times may be automatically computed for each work package, from which work center loads may be automatically totalled. Rescheduling can then be performed to level load facilities and manpower.

One potentially difficult material control problem arises as a result of this methodology's emphasis on compressing outfit duration (really total contract duration) and the dual role played by outfit items as system components and work package or "pallet" components. The problem involves keeping track of those items (or their source materials) which have been ordered early on (or are already available in inventory), on the basis of preliminary system material lists, and those needed in a interim product-based work package material list which have not been ordered or are not available in inventory. The simple information structure in the model of Fig. 12 would eliminate any confusion in this regard.

The methodology of Outfit Planning truly offers the potential for dramatic productivity improvements and we believe the availability of a product model such as this can significantly assist in its implementation and execution.

Fig. 13, then, summarizes some of the effects on the planning function of the use of a Product Information System

#### **BENEFITS IN PRODUCTION CONTROL/PRODUCTION**

As we have already seen the use of engineered standards in the product model allows reliable schedules to be established from solid work content estimates for each work package. This by itself would simplify production control as there would exist much less variance or exception conditions requiring control in the first place.

## BENEFITS IN PLANNING

- 1, EASE WITH WHICH THE DESIGN CAN BE DECOMPOSED INTO UNITS AND EVALUATED FOR PRODUCIBILITY, ETC.
- 2, POTENTIAL FOR AUTOMATED LABOR BUDGET AND JOB DURATION ESTIMATES GENERATION FOR SCHEDULING BASED ON DESIGN DATA AVAILABILITY AND THE USE IN THE PRODUCT MODEL OF ENGINEERED STANDARDS.
- 3, PROVIDES TOOL FOR SUPPORT OF OUTFIT PLANNING.

Fig. 13. Planning Benefits Summary

Where exception conditions do occur, such as when a major piece of equipment goes down for a prolonged period, the ability to reload facilities and manpower and reschedule work packages quickly to achieve level, or minimum cost loading would be very beneficial. This reloading and rescheduling could be carried out as often as the yard felt necessary.

The benefits for the shops themselves come more or less for free as a result of the fact that a more complete design and planning job can be accomplished prior to their receipt of a work order and due to the fact that the jobs are issued in accordance with a schedule which is based on better-informed decision making by production control.

However the shops should benefit as well by receiving computer-generated job documentation which is accurate and which can be customized easily to meet each shop's and, if necessary, each job's particular requirements. As an example Fig. 14 represents an unit isometric which could be computer-generated to supplement the assembly work package for the unit. Fig. 15 summarizes some of the benefits for production control and the shops of the use of a Product Information System.

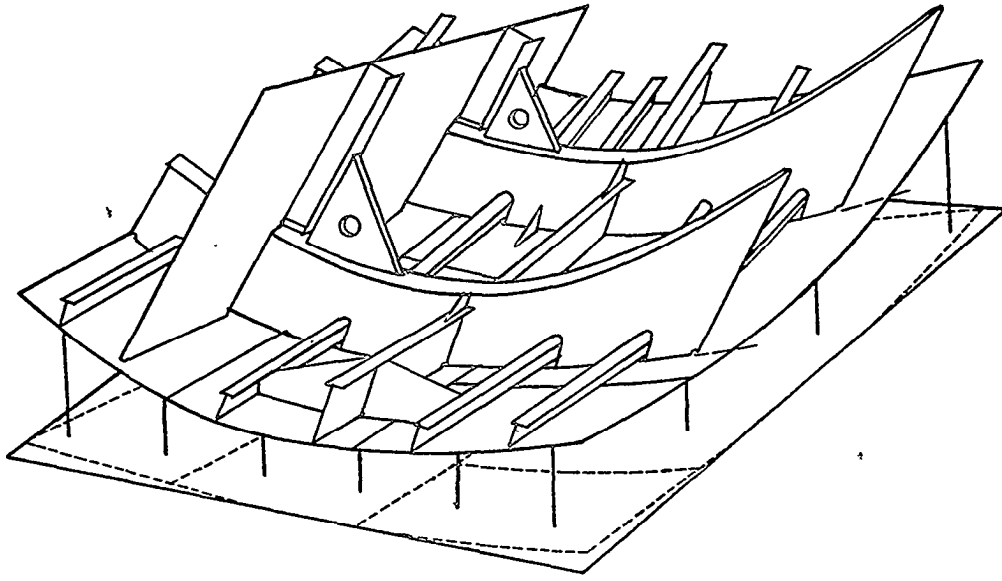


Fig. 14. Example Unit Isometric Shop Sketch

#### BENEFITS IN PRODUCTION CONTROL/PRODUCTION

- 1, MORE RELIABLE SCHEDULES DUE TO APPLICATION OF ENGINEERED STANDARDS,
- 2, ABILITY TO AUTOMATICALLY LEVEL-LOAD FACILITIES AND MANPOWER,
- 3, ACCURATE WORK PACKAGE BILL OF MATERIALS DIRECTLY AVAILABLE--UNAVAILABILITY OF AN ITEM CAN BE AUTOMATICALLY FLAGGED,
- 4, COMPUTER-GENERATED SHOP SKETCHES CAN BE TAILORED TO PRODUCTION NEEDS,

Fig. 15. Summary of Production Control/Production Benefits



## **Summary**

To summarize, a product model is all about properly organizing information. The fact that its on a computer simply means that those that need to use it can get it quickly and in a useful form and that application programs can readily access it.

In terms of implementation any commercially available data base management system which supports network information structures is capable of accommodating such product models. Because of the use of such off-the-shelf database software it would be a straightforward task to interface existing applications software to the product model, thus enhancing each yard's current investment in their operational software.

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